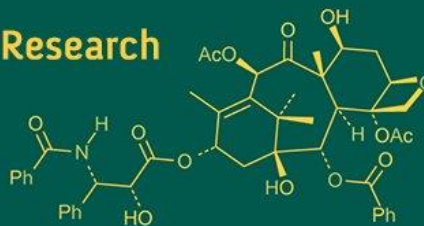


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Effect of foliar application of potassium silicate on growth, yield and quality of banana

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Abstract

Banana cv. Grand Naine is an economically paramount fruit crop possessing heavy nutrient demands, whose commercial output and postharvest durability are often constrained by inadequate nutrient assimilation, lodging vulnerability and rapid fruit softening. A field experiment was executed at the Department of Fruit Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, India, using a Factorial Randomized Block Design (FRBD) with three replications to determine the influence of foliar potassium silicate (K_2SiO_3) concentrations A_1 : Control (water spray), A_2 : 0.2%, A_3 : 0.4% and phenological spraying stages B_1 : 3 months after planting, B_2 : 5 Months After Planting, B_3 : 7 Months After Planting, B_4 : at denavelling, B_5 : 1 month after denavelling. In strict accordance with experimental requirements, observations were focused on key growth parameters, yield attributes, bunch and finger characteristics, leaf macronutrients (N, P, K), chemical quality indices and the benefit: cost (B:C) ratio. Foliar application of 0.4% K_2SiO_3 applied at 7 MAP (A_3B_3) optimized vegetative performance, producing significantly highest leaf area (0.98 dm^2), functional leaves per plant (25.67), total leaf chlorophyll (2.77 mg g^{-1}), leaf N (2.59%), leaf P (0.38%) and leaf K (3.30%). In contrast, 0.4% K_2SiO_3 administered at the denavelling stage (A_3B_4) optimized reproductive and fruit traits, yielding maximum bunch weight (23.00 kg), fingers per hand (19.97), finger weight (214.80 g), fruit yield ($23.00 \text{ kg plant}^{-1}$; 85.17 t ha^{-1}), Total Soluble Solids (21.90 °Brix), reducing sugars (11.92%) and ascorbic acid ($10.89 \text{ mg } 100\text{g}^{-1}$), while minimizing titratable acidity (0.20%) and pseudostem lodging (25.00%). The A_3B_4 schedule delivered the highest economic return with a B:C ratio of 2.25 compared to 1.89 in the unsprayed control. Dual-stage foliar supplementation of 0.4% K_2SiO_3 at 7 MAP and denavelling is recommended as a highly profitable management practice for high-density banana plantations.

Keywords: *Musa paradisiaca*, Grand Naine, Potassium silicate, Denavelling, Leaf nutrient dynamics, Chlorophyll, TSS, B:C ratio

1. Introduction

Banana (*Musa paradisiaca* L.) is globally celebrated as one of the most vital fruit crops and food security staples, widely recognized as 'Kalpataru' in the Indian subcontinent due to its perennial bearing habit and multifaceted economic utility. Commercial cultivation across India, especially in the high-production tracts of Maharashtra, is overwhelmingly anchored on cultivar Grand Naine owing to its high yield potential, compact stature, uniform finger conformation and supreme consumer preference (Robinson and Galan Sauco, 2010) [22]. However, the crop is exceptionally fast-growing and nutrient-exhaustive, consuming massive quantities of primary macronutrients especially potassium to sustain rapid phyllochron emergence, pseudostem expansion, floral initiation and subsequent bunch filling (Thangaselvabai *et al.*, 2009; ICAR-NRCB, 2021) [9, 25]. Suboptimal nutrient transport, physiological stresses and pseudostem structural instability often impede orchards from realizing their genetic yield potential.

In modern horticultural nutrition, silicon (Si) has emerged as an indispensable quasi-essential biostimulant that fortifies plant mechanical tissues and mitigates diverse biotic and abiotic stresses (Epstein, 1999; Ma and Yamaji, 2006) [7, 11]. Foliar application of potassium silicate (K_2SiO_3) provides a strategic dual nutritional advantage by concurrently supplying bioavailable silicon (SiO_2) and ionic potassium (K^+). Soluble silicon deposits into leaf epidermal and cuticular matrices as amorphous silica (phytoliths), promoting an erect leaf architecture, improving solar radiation capture, reducing cuticular transpiration and

stabilizing cellular membranes (Asmar *et al.*, 2013) [5]. Simultaneously, potassium serves as a master enzyme activator in carbon assimilation, sucrose phloem loading and osmotic turgor maintenance (Vijayan *et al.*, 2021) [27]. Although the individual roles of potassium and silicon have been observed across various horticultural crops (Shehata *et al.*, 2018; Abidi *et al.*, 2023) [2, 24], empirical field investigations detailing the optimal concentration and stage-specific application timing of K_2SiO_3 in commercial banana production remain limited. Specifically, distinguishing between vegetative growth responses during peak canopy formation versus sink-filling responses following denavelling (terminal male bud excision) warrants in-depth elucidation. Accordingly, the present study was conducted to evaluate the influence of foliar application of potassium silicate concentrations and application timings on vegetative growth parameters, yield attributes, bunch and finger metrics, foliar NPK accumulation, biochemical fruit quality and enterprise economics in banana cv. Grand Naine.

2. Materials and Methods

The field investigation was conducted during the 2025-2026 agricultural cropping season at the Department of Fruit Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India.

The trial was established in a Factorial Randomized Block Design (FRBD) comprising fifteen treatment combinations replicated three times, with four uniform tissue-cultured Grand Naine plants per replication. Factor A comprised three potassium silicate foliar concentrations: A₁ [Control (water spray)], A₂ [0.2% K_2SiO_3] and A₃ [0.4% K_2SiO_3]. Factor B encompassed five phenological application stages: B₁ [3 months after planting (MAP)], B₂ [5 MAP], B₃ [7 MAP], B₄ [at denavelling], and B₅ [1 month after denavelling].

Observations were taken strictly on selected research parameters: (A) Growth parameters: functional leaves per plant (counted at shooting), leaf area (dm^2 , estimated on the 3rd fully expanded leaf using Murry's formula: Length $\times$ Width $\times$ 0.8) and total leaf chlorophyll content ($mg\ g^{-1}$ fresh weight, extracted in DMSO and measured spectrophotometrically at 645 nm and 663 nm; Sadasivam and Manickam, 1992) [23]; (B) Yield parameters: fruit yield per plant ($kg\ plant^{-1}$) and total fruit yield ($t\ ha^{-1}$); (C) Bunch and finger parameters: bunch weight (kg), hands per bunch, fingers per hand and single finger weight (g); (D) Leaf nutrient status: total leaf N (%), P (%), and K (%)

determined on the 3rd fully expanded leaf at shooting, digested in di-acid ($HNO_3:HClO_4$, 9:4 v/v) and estimated by micro-Kjeldahl distillation, vanadomolybdate yellow spectrophotometry (420 nm), and flame photometry, respectively (Jackson, 1973; Piper, 1966) [8, 17]; (E) Pulp chemical observations: Total Soluble Solids ($^{\circ}Brix$, digital refractometer), titratable acidity (%), titrated against 0.1 N NaOH; Ranganna, 1991) [20], and ascorbic acid ($mg\ 100g^{-1}$ pulp, 2,6-dichlorophenol indophenol titration; Ranganna, 1977) [19] and (F) Benefit: Cost (B:C) ratio: computed by dividing gross returns by total production cost per hectare. Data were statistically processed via ANOVA for Factorial RBD, with statistical significance determined by the F-test, and critical differences (CD) were calculated at $p = 0.05$ (Panse and Sukhatme, 1976) [14].

3. Results and Discussion

3.1 Growth Parameters and Total Leaf Chlorophyll

The experimental results revealed that foliar application of potassium silicate exerted a highly significant influence on functional leaf production, expanded leaf surface area and total leaf chlorophyll accumulation (Table 1). Foliar feeding with 0.4% K_2SiO_3 (A₃) recorded the maximum functional leaf count ($23.07\ plant^{-1}$), largest leaf area ($0.76\ dm^2$) and highest chlorophyll content ($2.52\ mg\ g^{-1}$), significantly outperforming the untreated control (21.54 leaves, $0.44\ dm^2$, and $1.92\ mg\ g^{-1}$ chlorophyll, respectively). With respect to spraying stages, foliar application at 7 MAP (B₃) generated peak leaf area ($0.71\ dm^2$) and chlorophyll concentration ($2.44\ mg\ g^{-1}$), while sprays one month after denavelling preserved the highest leaf retention (22.45 leaves $plant^{-1}$).

The interaction between concentration and timing was statistically significant for leaf area and leaf count. Plants treated with 0.4% K_2SiO_3 at 7 MAP (A₃B₃) registered the highest individual leaf area ($0.98\ dm^2$), leaf production (25.67 leaves $plant^{-1}$) and peak total chlorophyll ($2.77\ mg\ g^{-1}$). This vegetative superiority is linked to the mechanical and biochemical benefits of silicon and potassium. Deposited silicon reinforces cell walls and leaf petioles, maintaining upright leaf orientation and improving canopy light interception while preventing chlorophyll degradation (Asmar *et al.*, 2013) [5]. Potassium activates nitrate reductase and Rubisco, promoting tetrapyrrole ring synthesis and cellular turgidity (Vijayan *et al.*, 2021) [27]. These findings corroborate the results of Panchal *et al.*, (2020) [13] and Aiman Takrim *et al.*, (2021) [3] in banana.

Table 1: Effect of potassium silicate concentration and application timing on growth, yield and bunch weight of banana cv. Grand naine

Treatment	Leaves / Plant	Leaf area (dm^2)	Chlorophyll ($mg\ g^{-1}$)	Yield ($kg/plant$)	Yield ($t\ ha^{-1}$)	Bunch weight (kg)
Factor A						
A ₁	21.54	44.57	1.92	17.00	62.95	17.00
A ₂	20.80	60.39	2.31	19.70	72.95	19.70
A ₃	23.07	76.47	2.52	20.64	76.43	20.64
F-test	Sig	Sig	Sig	Sig	Sig	Sig
CD at 5%	0.13	0.27	2.76	0.27	1.00	0.27
Factor B						
B ₁	21.33	55.42	2.17	18.00	66.65	18.00
B ₂	20.33	60.75	2.31	18.33	67.87	18.33
B ₃	20.33	71.60	2.44	18.97	70.23	18.97
B ₄	21.33	58.22	2.23	20.47	75.78	20.47
B ₅	22.45	56.40	2.11	19.80	73.31	19.80
F-test	Sig	Sig	Sig	Sig	Sig	Sig

CD at 5%	0.17	0.34	3.56	0.35	1.30	0.35
A×B						
A ₁ B ₁	20.67	42.02	1.88	17.00	62.95	17.00
A ₁ B ₂	20.33	45.42	1.93	16.80	62.21	16.80
A ₁ B ₃	23.33	48.12	1.99	17.20	63.69	17.20
A ₁ B ₄	21.33	44.23	1.91	16.90	62.58	16.90
A ₁ B ₅	22.00	43.07	1.87	17.10	63.32	17.10
A ₂ B ₁	21.00	56.12	2.20	18.20	67.38	18.20
A ₂ B ₂	19.33	61.42	2.38	18.80	69.61	18.80
A ₂ B ₃	21.67	68.15	2.55	19.50	72.21	19.50
A ₂ B ₄	20.33	59.22	2.27	21.50	79.61	21.50
A ₂ B ₅	21.67	57.07	2.14	20.50	75.91	20.50
A ₃ B ₁	22.33	68.12	2.42	18.80	69.61	18.80
A ₃ B ₂	21.33	75.42	2.61	19.40	71.84	19.40
A ₃ B ₃	25.67	98.53	2.77	20.20	74.78	20.20
A ₃ B ₄	22.33	71.22	2.50	23.00	85.17	23.00
A ₃ B ₅	23.67	69.07	2.31	21.80	80.72	21.80
F-test	Sig	Sig	NS	Sig	Sig	Sig
CD at 5%	0.30	0.59	NS	0.60	2.54	0.60

3.2 Yield Attributes and Bunch Parameters

Yield metrics and bunch architecture responded markedly to potassium silicate treatments (Table 1 and Table 2). Foliar feeding with 0.4% K₂SiO₃ (A₃) recorded maximum mean bunch weight (20.64 kg), plant yield (20.64 kg plant⁻¹) and hectare yield (76.43 t ha⁻¹), reflecting a 21.41% yield increase over the control (17.00 kg plant⁻¹; 62.95 t ha⁻¹). Application timing demonstrated a distinct peak at the denavelling stage (B₄), producing an average bunch weight of 19.80 kg, yield of 20.47 kg plant⁻¹, and 75.78 t ha⁻¹, significantly outperforming early vegetative sprays at 3 MAP (18.00 kg plant⁻¹; 66.65 t ha⁻¹).

The interaction between concentration and timing was statistically significant for all yield and bunch attributes. The treatment combination of 0.4% K₂SiO₃ applied at denavelling (A₃B₄) registered the absolute highest fruit yield per plant (23.00 kg), total productivity (85.17 t ha⁻¹), bunch weight (23.00 kg), hands per bunch (9.22), fingers per hand (19.97) and individual finger weight (214.80 g), compared to only 16.90 kg bunch weight and 62.58 t ha⁻¹ in the control (A₁B₄). This pronounced response is explained by source-sink dynamics: removing the terminal male bud eliminates competing non-productive sinks, directing absorbed potassium and silicon straight into the developing ovaries, which prevents fruitlet drop, enhances mitotic division and drives rapid finger filling (Patil and Jagadeesh, 2016; Vaishnavi *et al.*, 2022) [16, 26].

3.3 Leaf Nutrient Dynamics (Total N, P and K Content)

Total leaf nitrogen, phosphorus and potassium contents at shooting were significantly enhanced by potassium silicate treatments (Table 2). Foliar feeding with 0.4% K₂SiO₃ (A₃) established the highest foliar concentrations of N (2.18%), P (0.29%) and K (2.79%) relative to 1.35% N, 0.21% P and 2.55% K in the control (A₁). Spraying at 7 MAP (B₃) produced peak leaf nutrient accumulation across all timings (2.13% N, 0.29% P and 2.90% K). The interaction of 0.4% K₂SiO₃ applied at 7 MAP (A₃B₃) yielded the maximum leaf nutrient status: 2.59% N, 0.38% P and 3.30% K, reflecting an improvement of 1.14% N, 0.17% P and 0.88% K over the untreated control.

The substantial enhancement of foliar N, P and K status under K₂SiO₃ sprays during rapid vegetative development (7 MAP) illustrates Si-mediated physiological upregulation. Exogenous silicon stimulates root physiological activity, increases nitrate reductase enzyme activity and regulates plasma membrane H⁺-ATPase pumps, thereby accelerating active nutrient acquisition and transpiration flow (Patil *et al.*, 2017; Panchal *et al.*, 2020) [13, 15]. Simultaneously, direct foliar absorption of potassium improves leaf sap ionic concentrations and facilitates phosphate anion translocation. As plants transition to reproductive heading, these foliar reserves are remobilized to sustain developing bunches, confirming the importance of building reserves at 7 MAP (Vijayan *et al.*, 2021) [27].

Table 2: Effect of potassium silicate on bunch architecture, finger weight, and leaf macronutrient status (N, P, K)

Treatment	Hands / Bunch	Fingers / Hand	Finger Wt. (g)	Leaf N (%)	Leaf P (%)	Leaf k (%)
Factor A						
A ₁	8.23	15.28	163.90	1.35	0.21	2.55
A ₂	8.56	17.30	182.96	1.90	0.26	2.67
A ₃	8.82	18.05	193.68	2.18	0.29	2.79
F-test	Sig	Sig	Sig	Sig	Sig	Sig
CD at 5%	0.002	0.22	2.32	0.02	0.01	0.06
Factor B						
B ₁	8.34	15.60	163.93	1.74	0.22	2.50
B ₂	8.46	16.25	177.80	1.97	0.25	2.65
B ₃	8.59	17.17	185.23	2.13	0.29	2.90
B ₄	8.82	18.21	193.17	1.63	0.26	2.70
B ₅	8.48	17.17	180.77	1.51	0.24	2.55
F-test	Sig	Sig	Sig	Sig	Sig	Sig

CD at 5%	0.003	0.28	3.00	0.02	0.01	0.08
A×B						
A ₁ B ₁	8.12	15.20	162.20	1.35	0.20	2.65
A ₁ B ₂	8.21	15.25	163.50	1.40	0.20	2.58
A ₁ B ₃	8.23	15.30	164.80	1.45	0.21	2.42
A ₁ B ₄	8.38	15.35	166.10	1.30	0.21	2.46
A ₁ B ₅	8.17	15.30	162.90	1.25	0.21	2.52
A ₂ B ₁	8.36	15.60	165.40	1.80	0.23	2.48
A ₂ B ₂	8.46	16.40	178.50	2.10	0.26	2.62
A ₂ B ₃	8.62	17.60	188.20	2.35	0.30	2.98
A ₂ B ₄	8.85	19.30	198.60	1.70	0.28	2.72
A ₂ B ₅	8.51	17.60	184.10	1.55	0.25	2.54
A ₃ B ₁	8.54	160	164.20	2.05	0.24	2.38
A ₃ B ₂	8.71	17.10	191.40	2.40	0.27	2.75
A ₃ B ₃	8.88	18.60	202.70	2.59	0.38	3.30
A ₃ B ₄	9.22	19.97	214.80	1.90	0.29	2.92
A ₃ B ₅	8.76	18.6	195.3	1.70	0.25	2.60
F-test	Sig	Sig	Sig	Sig	Sig	Sig
CD at 5%	0.005	0.49	5.20	0.04	0.02	0.14

3.4 Fruit Biochemical Quality and Economic Feasibility

Biochemical fruit quality and economic returns were significantly improved by potassium silicate treatments (Table 3). Application of 0.4% K₂SiO₃ (A₃) recorded the highest Total Soluble Solids (19.50 °Brix) and ascorbic acid (9.58 mg 100g⁻¹), with the lowest titratable acidity (0.23%), compared to 17.50 °Brix, 7.36 mg 100g⁻¹ ascorbic acid and 0.28% acidity in the untreated control. Across application timings, spraying at denavelling (B₄) optimized pulp biochemistry, yielding 20.12 °Brix TSS, 9.58 mg 100g⁻¹ ascorbic acid and 0.23% acidity.

The interaction effect indicated that 0.4% K₂SiO₃ applied at denavelling (A₃B₄) achieved the absolute highest TSS

(21.90 °Brix), ascorbic acid (10.89 mg 100g⁻¹) and the lowest titratable acidity (0.20%). The potassium-mediated activation of sucrose phosphate synthase and starch-hydrolyzing enzymes accelerates the conversion of starch to soluble sugars during ripening (Rakesh, 2018) [18]. Concurrently, silicon protects ascorbic acid from enzymatic oxidation by inhibiting ascorbic acid oxidase and reinforcing cellular membrane integrity (Al-Muhe and Abdul-Wahid, 2023) [4]. In economic terms, treatment A₃B₄ recorded the highest Benefit: Cost (B:C) ratio of 2.25 compared to 1.89 in the control (A₁B₄), demonstrating that substantial yield gains (85.17 t ha⁻¹) and improved fruit quality significantly exceed the minor costs of the treatment.

Table 3: Effect of potassium silicate on fruit biochemical quality and Benefit: Cost ratio of banana cv. Grand naine

Treatment	TSS (°B)	Titratable acidity (%)	Ascorbic acid (mg 100g ⁻¹)	Benefit: Cost ratio
Factor A				
A ₁	17.50	0.28	7.36	1.93
A ₂	18.80	0.25	8.94	2.02
A ₃	19.50	0.23	9.58	2.06
F-test	Sig	Sig	Sig	Sig
CD at 5%	0.28	0.005	0.17	0.02
Factor B				
B ₁	17.20	0.27	7.60	1.93
B ₂	17.77	0.27	8.09	1.95
B ₃	19.07	0.25	8.97	2.01
B ₄	20.12	0.23	9.58	2.11
B ₅	19.02	0.24	8.90	2.03
F-test	Sig	Sig	Sig	Sig
CD at 5%	0.36	0.006	0.22	0.03
A×B				
A ₁ B ₁	17.40	0.28	7.30	1.98
A ₁ B ₂	17.50	0.28	7.35	1.94
A ₁ B ₃	17.60	0.28	7.40	1.92
A ₁ B ₄	17.50	0.27	7.45	1.89
A ₁ B ₅	17.40	0.28	7.30	1.91
A ₂ B ₁	17.10	0.28	7.50	1.90
A ₂ B ₂	17.80	0.27	8.20	1.95
A ₂ B ₃	19.20	0.24	9.50	2.03
A ₂ B ₄	20.90	0.22	10.40	2.18
A ₂ B ₅	19.20	0.24	9.10	2.04
A ₃ B ₁	17.10	0.27	8.00	1.90
A ₃ B ₂	18.00	0.25	8.70	1.96

A ₃ B ₃	20.40	0.21	10.00	2.09
A ₃ B ₄	21.90	0.20	10.89	2.25
A ₃ B ₅	20.3	0.21	10.30	2.12
F-test	Sig	NS	Sig	Sig
CD at 5%	0.64	-	0.38	0.05

4. Conclusion

The findings of this investigation demonstrate that foliar application of potassium silicate provides substantial, stage-specific physiological benefits in banana cv. Grand Naine. Foliar application of 0.4% K₂SiO₃ at 7 months after planting (A₃B₃) significantly stimulates vegetative vigor, expanding leaf area (0.98 dm²), functional leaf longevity (25.67 leaves plant⁻¹), total chlorophyll (2.77 mg g⁻¹) and building maximum foliar macronutrient reserves (2.59% N, 0.38% P, and 3.30% K). In contrast, applying 0.4% K₂SiO₃ at the denavelling stage (A₃B₄) optimizes reproductive sink strength and bunch architecture, resulting in superior bunch weight (23.00 kg), fingers per hand (19.97), individual finger weight (214.80 g), total yield (85.17 t ha⁻¹) and premium pulp quality (21.90 °Brix TSS, 10.89 mg 100g⁻¹ ascorbic acid and 0.20% titratable acidity). Economically, the A₃B₄ schedule delivered the highest B:C ratio of 2.25 compared to 1.89 in the unsprayed control. A targeted foliar supplementation protocol combining 0.4% K₂SiO₃ at 7 MAP and again at denavelling is recommended for commercial banana growers seeking higher productivity, lodging resistance and superior financial returns.

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